



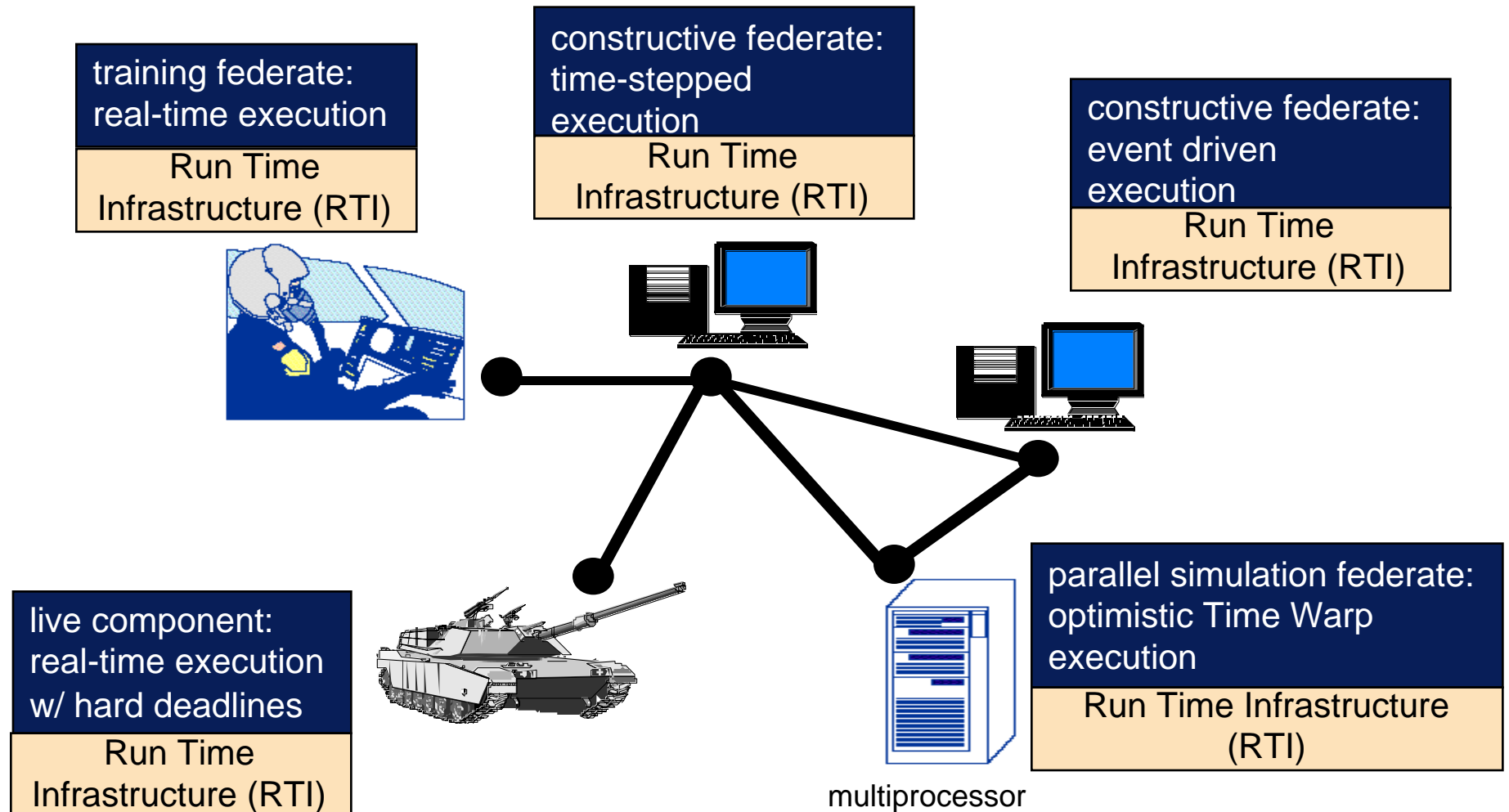
# **Time Management in the HLA**

## ***Baseline Definition***

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# Challenge: Time Management Interoperability

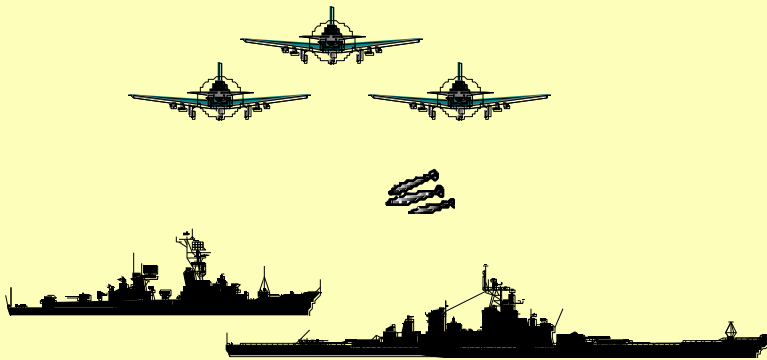


Goal: provide services to support interoperability among federates with different local time management schemes in a single federation execution.



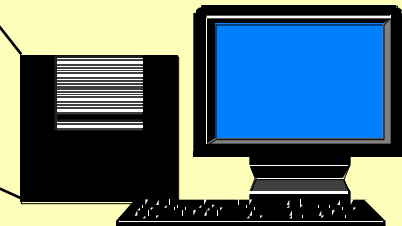
# Time

- *physical system*: the actual or imagined system being modeled
- *simulation*: a system that emulates the behavior of a physical system



*physical system*

```
main()
{ ...
  double clock;
  ...
}
```



*federate (a simulation)*

- ***physical time***: time in the physical system (e.g., 0000 to 1700 hours, December 7, 1941)
- ***simulation time***: representation of physical time within the simulation
  - ***federation time axis (FTA)***: a totally ordered sequence of values representing physical time (floating point values in interval [0.0, 17.0])
  - ***federate time***: a specific federate's current point on FTA (e.g., 4.0)
- ***wallclock time***: time during the execution of the simulation, usually output from a hardware clock (e.g., 1330 to 1700 hours on February 24, 1997)



# Time Management

*Time management is concerned with the mechanisms used by federates to advance along the federation time axis*

*paced (constrained) vs. unpaced (unconstrained) execution*

- **(scaled) real-time execution:** each federate is paced so federate time advances at a rate  $S$  times faster or slower than wallclock time
- **as-fast-as-possible execution:** no fixed relationship exists between advances in federate and wallclock time

*independent vs. coordinated time advances*

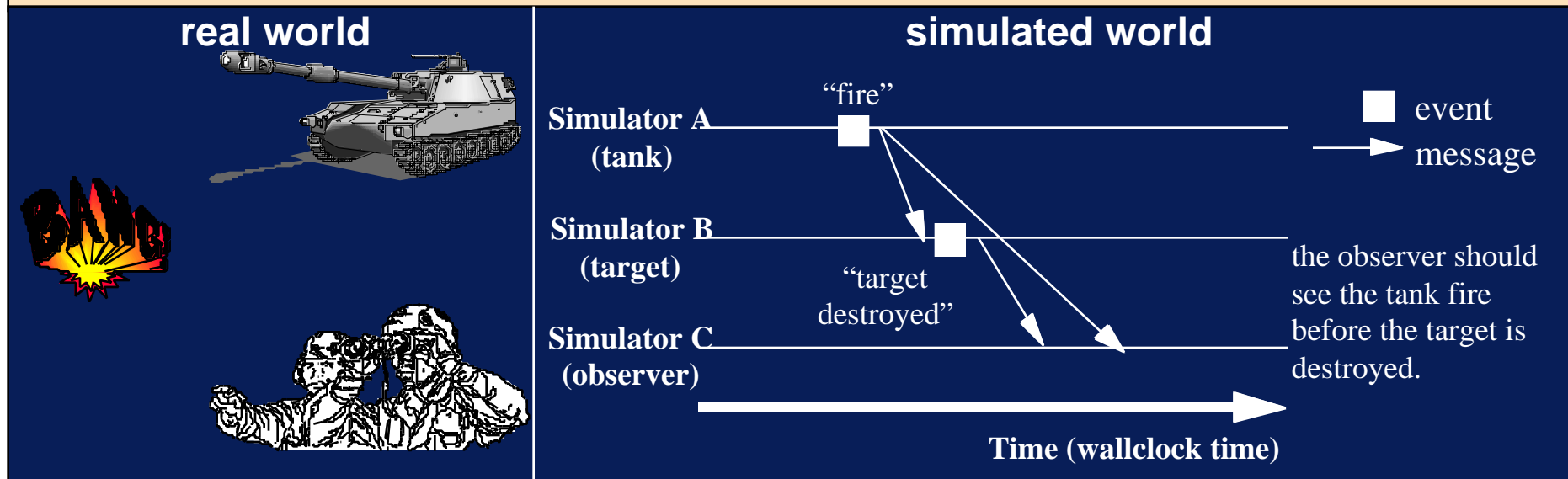
- **independent (e.g., training):** each federate advances its federate time independently of other federates  
***federate time same as wallclock time (scaled, plus an offset)***
- **coordinated (e.g., analysis):** time advances are coordinated to ensure the federation preserves before/after relationships in the physical system  
***federate time same as logical time***

example	paced?	time advance
DIS training exercise	yes	<i>independent</i>
ALSP (human-in-the-loop)	yes	<i>coordinated</i>
ALSP (as-fast-as-possible)	no	<i>coordinated</i>



# Causality

- “Things” happen in the real world in a certain order (e.g., cause & effect).
- It should appear that events in the simulated world happen in the same order as the real world actions that they represent.



Causality: If event A “*happens before*” event B, the message for A should be delivered before the message for B

If the message for the “fire” event is delayed in the network, the observer will “see” the target is destroyed before the tank fired upon it!

Temporal anomalies such as this may or may not be acceptable, depending on the federation’s goals



# Message Ordering Services

The baseline HLA provides two types of message ordering:

- **receive order:** messages passed to federate in order of reception
- **time stamp order (TSO):** successive messages passed to federate have non-decreasing time stamps

Property	Receive Order	Time Stamp Order (TSO)
Latency	<i>low</i>	<i>higher</i>
reproduce before and after relationships?	<i>no</i>	<i>yes</i>
all federates see same ordering of events?	<i>no</i>	<i>yes</i>
execution repeatable?	<i>no</i>	<i>yes</i>
typical applications	<i>training, T&amp;E</i>	<i>analysis</i>

- **receive order** minimizes latency, does not prevent temporal anomalies
- **TSO** prevents temporal anomalies, but has somewhat higher latency



# Logical Time

Classical discrete event simulation programs process all events in time stamp order

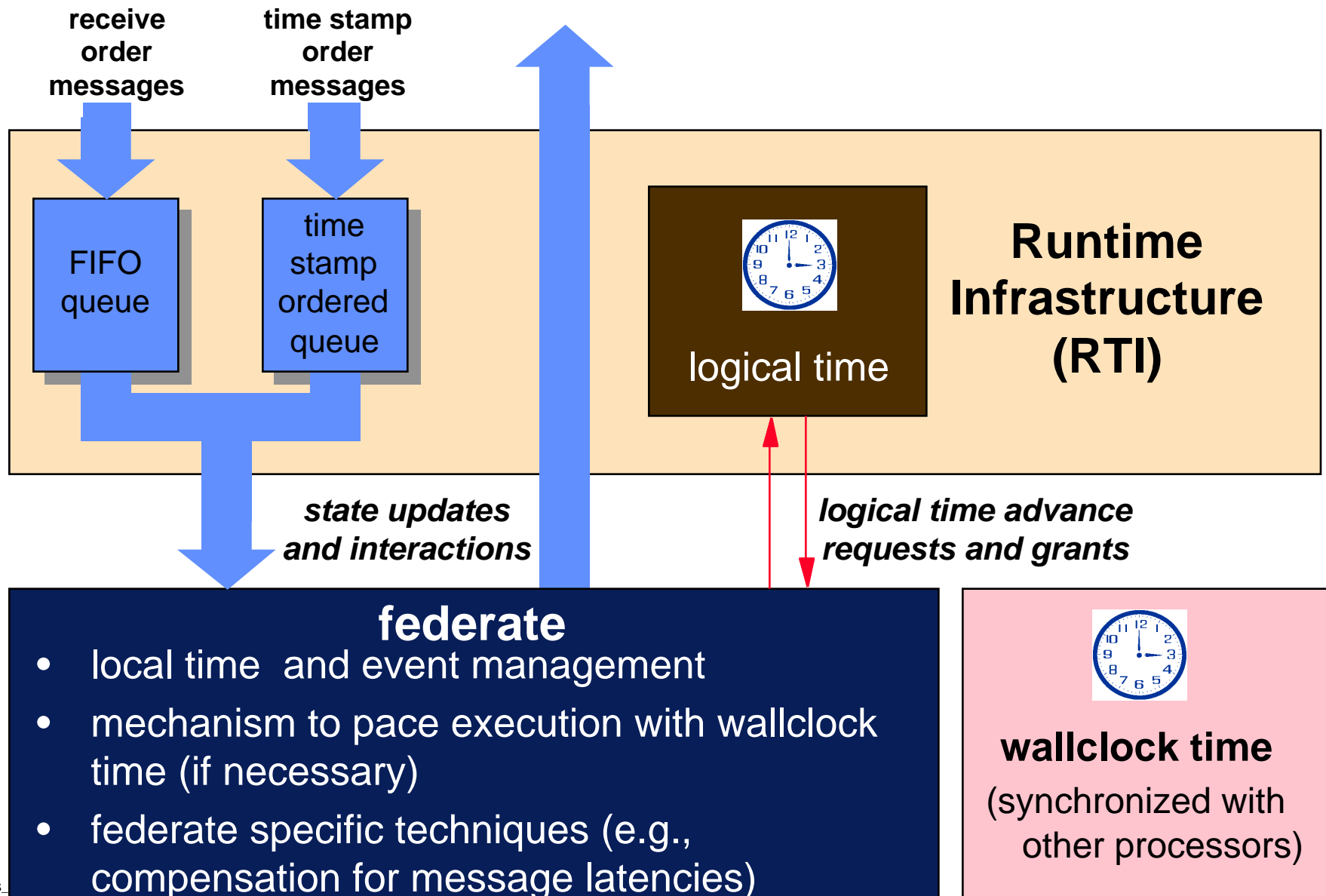
A mechanism is required to enable federates to interleave processing of local events with those received from other federates

**Logical time (applicable to coordinated time advance federates):**

- if the logical time of a federate is  $T$ , the RTI guarantees no more TSO messages will be passed to the federate with time stamp  $< T$
- local events with time stamp  $< T$  can be “safely” processed
- logical time in a federate only advances when that federate explicitly requests an advance:
  - Time Advance Request ( $T$ ): requests advance to time  $T$
  - Next Event Request ( $T$ ): requests advance to time stamp of next TSO message, or  $T$ , which ever is smaller
  - RTI issues Time Advance Grant( $T'$ ) when logical time advanced to  $T'$
- federates responsible for pacing logical time advances with wallclock time in (scaled) real-time executions



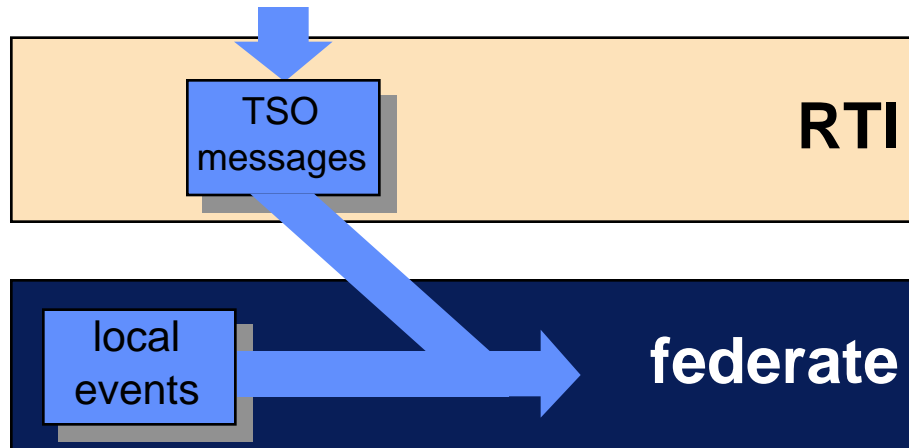
# Time Management Services







# Example: Event Driven Federate



Goal: merge TSO messages (events from other federates) with local events so all events are processed in time stamp order

```
/* now is a local variable tracking the logical time of the federate */  
while (simulation still in progress)
```

```
    TSlocal = time stamp of next local event notice
```

```
    invoke Next Event Request (TSlocal) service
```

```
        Receive state updates and interactions, send new updates and interactions
```

```
        honor RTI service request for Time Advance Grant
```

```
    if (no TSO message(s) received in above RTI service request)
```

```
        now = TSlocal
```

```
        process the next local event notice send new updates and interactions
```

```
    else
```

```
        now = time stamp of last TSO message delivered to federate
```





# Optimistic Time Management Services

Mechanisms to ensure events are processed in time stamp order:

- conservative: protocols to *avoid* out of order event processing (e.g., CMB)
- optimistic: *detect* out-of-order event processing, *recover* (e.g., Time Warp)

## Requirements

- support federations including conservative and/or optimistic federates
- federates not aware of local time management mechanism of other federates (optimistic or conservative)
- optimistic events (events that may be later canceled) cannot be delivered to conservative federates that cannot roll back
- optimistic events should be delivered to other optimistic federates
- individual federates may be sequential or parallel simulations

HLA time management services for optimistic federates:

- early release of messages to optimistic federates (**Flush Queue Request and Grant**)
- cancelation of previously sent messages: anti-messages (**Retract**)
- provide sufficient information to optimistic federate to compute *Global Virtual Time* locally (**LBTS**)



# Summary: HLA Time Management

## Functionality:

- support for a variety of styles of federation executions
  - real-time **vs.** scaled real-time **vs.** as-fast-as-possible executions
  - no causal guarantees **vs.** repeatable, causal executions
- allows federates with different time management requirements (and local TM mechanisms) to be combined within a single federation execution
  - DIS-style training simulations
  - simulations with hard real-time constraints
  - event-driven simulations
  - time-stepped simulations
  - optimistic simulations

## HLA Time Management services:

- receive order and time stamp order message delivery
- logical time
  - time advance mechanisms
  - no TSO messages in a federate's "past"